REMARKS

- Claims 1-4 and 6-20 were previously pending.
- Claims 1-4 and 6-20 are currently amended.
- Claims 1-4 and 6-20 are currently pending.

Claim Rejections Under 35 USC § 103(a)

Claims 1-4 and 6-20 were rejected under 35 USC § 103(a) as being unpatentable over **Haugen** et al., "Simulation of Independent Reservoirs Couple by Global Production and Injection Constraints," in view of **Briens** et al., "Application of Sequential Staging of Tasks to Petroleum Reservoir Modeling," in view of U.S. Patent No. 6,108,608 to **Watts**, "Method of Estimating Properties of a Multi-Component Fluid Using Pseudocomponents," in view of **Scott** "Application of Parallel (MIMD) Computers to Reservoir Simulation."

Independent Claims 1, 2 and 14

Independent Claims 1, 2, and 14 have been amended to more particularly point out and distinctly claim the subject matter recited.

Claim 1 defines a computer-executable method, claim 2 defines a controller, and claim 14 defines instructions stored on a computer-readable storage medium, for coupling multiple reservoir and network simulations:

Claim 1

1. A computer-executable method of coupling multiple reservoir and network simulations comprising:

providing an open message-passing interface that communicates with black oil model reservoir simulations, compositional model reservoir simulations, and different types of surface network simulations;

initiating a first reservoir simulation for one or more physical parameters of a first reservoir, the first reservoir simulation using a first fluid model;

initiating a second reservoir simulation for the one or more physical parameters of a second reservoir, the second reservoir simulation using a second fluid model;

initiating a network simulation to model a network for coupling the first reservoir and the second reservoir to a surface facility;

selecting maximum synchronization intervals to limit controller time steps;

defining network balancing times based on the controller time steps;

applying the controller time steps via the open message-passing interface to the advancement through time of the first reservoir simulation, the second reservoir simulation, and the network simulation, each controller time step enabling the first reservoir simulation, the second reservoir simulation, and the network simulation to each take a different number of non-identical time steps to advance to the start of a next controller time step;

varying the duration of the controller time steps in response to a production rate or an injection rate of the first reservoir simulation or the second reservoir simulation;

translating via the open message-passing interface each of a first hydrocarbon fluid stream of the first reservoir simulation and a second hydrocarbon fluid stream of the second reservoir simulation to a common fluid model of the controller by converting pseudo-components of each of the first

hydrocarbon fluid stream and the second hydrocarbon fluid stream to a super-set of pseudo-components used in the first reservoir simulation and the second reservoir simulation; and

initiating network balancing at a corresponding point in each controller time step.

Claim 2

2. A controller for coupling multiple reservoir and network simulations comprising:

means for interfacing via open message-passing with different types of simulation tasks including black oil model reservoir simulations, compositional model reservoir simulations, and different types of surface networks simulations;

means for initiating a first reservoir simulation for one or more physical parameters of a first reservoir, the first reservoir simulation using a first fluid model;

means for initiating a second reservoir simulation for the one or more physical parameters of a second reservoir, the second reservoir simulation using a second fluid model;

means for initiating a network simulation to model a network for coupling the first reservoir and the second reservoir to a surface facility;

means for selecting a maximum synchronization time to define controller time steps and network balancing times based on the controller time steps;

means for applying the controller time steps to the advancement through time of the first reservoir simulation, the second reservoir simulation, and the network simulation, each controller time step enabling the first reservoir simulation, the second reservoir simulation, and the network simulation to each take a different number of non-identical time steps to advance to the start of a next controller time step;

means for dynamically adjusting the duration of the controller time steps when a production or injection rate in one of the simulations changes beyond a selected threshold;

means for translating each of a first hydrocarbon fluid stream of the first reservoir simulation and a second hydrocarbon fluid stream of the second reservoir simulation to a common fluid model of the controller by converting pseudo-components of each of the first hydrocarbon fluid stream and the second hydrocarbon fluid stream to a super-set of pseudo-components used in the first reservoir simulation and the second reservoir simulation; and

means for network balancing at a corresponding point in each of the controller time steps.

<u>Claim 14</u>

14. A computer readable storage medium containing instructions, which, when executed by a computer, perform a process comprising:

interfacing via open message-passing with different types of simulation tasks including black oil model reservoir simulations, compositional model reservoir simulations, and different types of surface network simulations;

initiating a first reservoir simulation for one or more physical parameters of a first reservoir, the first reservoir simulation using a first fluid model;

initiating a second reservoir simulation for the one or more physical parameters of a second reservoir, the second reservoir simulation using a second fluid model;

initiating a network simulation to model a network for coupling the first reservoir and the second reservoir to a surface facility;

selecting a maximum synchronization duration to define controller time steps and network balancing times based on the controller time steps;

applying the controller time steps to the advancement through time of the first reservoir simulation and the second reservoir simulation, each controller time step enabling different simulation tasks to each take a different number of non-identical time steps to advance to a next controller time step; and

dynamically varying the duration of the controller time steps in response to a production rate or an injection rate of the first reservoir simulation or the second reservoir simulation.

Cited Prior Art References

The cited prior art references, Haugen, Briens, Watts, and Scott, alone or in combination do not teach or suggest each element of any one of the independent claims.

Haugen

The Haugen reference describes coupling of reservoir simulation models, in which the reservoir simulations are coupled by group / global production and injection constraints. But Haugen does not disclose applying temporal synchronization processes to the independent reservoir simulations, other than the imposed constraints.

Briens

The Briens reference describes vectorization of large-scale compositional reservoir simulation (greater than 1000 cells) to speed up calculations and make the simulation practical on mainframe computers of the day (1990).

Briens describes breaking down a single large processing task via parallel computing among multiple processors. This includes staging, through system specific routines, which allows the synchronization of parallel processing events. (Page 431, cited by the Examiner.) The (sequential) staging and synchronization of parallel events, however, merely refers to allocating of processing instructions

among multiple coprocessors or similar workstations, not to synchronizing separate large-scale reservoir and surface network simulations.

The citation at issue on page 431 and cited by the Examiner refers to "synchronization of parallel events[9]." This "synchronization" refers to the execution of processor tasks that must be staged to avoid memory conflict. This staging can be provided by the 1988 version of "IBM Parallel FORTRAN" (Internal Reference No. 9, in Briens). By "synchronization," Briens does not appear to be referring to controlling multiple separate reservoir and network simulations, since accomplishing ***one*** simulation through staging of tasks is the upshot of the Briens reference.

Watts

Watts describes pseudo-components: utilized to estimate properties of a multi-component fluid. The Watts method assigns vectors to a characteristic of base components describing the multi-component fluid, and defines a pseudo-component as a subset of the assigned vectors. Watts does not appear to be suggesting super-sets of pseudo-components between multiple reservoir and network simulations.

Scott

Scott describes application of parallel computers to reservoir simulation. In a manner similar to Briens above, Scott seeks to divide up the large processing tasks of determining matrix coefficients and solving the corresponding sparse matrix for a ***single*** reservoir simulation, via parallel computing. Like Briens, Scott aims to speed up calculations and make a single simulation practical on mainframe computers of the day (1987).

Scott does not teach or suggest coupling multiple reservoirs, but rather, given the limited processing power of single processors available in 1988, tries to solve the question of how to run calculations for performing a single reservoir simulation in a practical manner, i.e., how to allocate different parts of the code for a single simulation to multiple processors through parallel computing.

Both Scott and Briens are concerned with gathering enough 1987-vintage processing power to realistically perform a ***single*** reservoir simulation (currently *millions* of individual grid cells with associated matrix coefficients to calculate--Briens considers 1000 grid cells to be large-scale). However, these two references, Scott and Briens, do not teach or suggest coupling multiple reservoir and network simulations. As pointed out by the Examiner in the rejection, page 2 of Scott discloses that multiprocessor computer systems can be thought of as a collection of independent SISD or SIMD systems connected by an extensive network or via shared memory that allows all of the processors to work together on a ***single problem***. (Page 2, last sentence under Parallel Computers, emphasis added.)

Indeed, the whole of Scott is dedicated to describing division of a single task (computation of matrix coefficients and solutions) into smaller parts that can be distributed. Scott does not teach or suggest messaging sufficient to couple and synchronize multiple reservoirs and network simulations, which was beyond the ken of Scott. Thus Scott states, "algorithm development for parallel computers is still in its infancy since most algorithms simply mimick those which were developed specifically for use on sequential machines." (Page 8, under Conclusions.) "The ***development of*** parallel algorithms for reservoir simulation ***must be considered*** if the next generation of supercomputers is to be used effectively by the petroleum industry." (Page 8, under Conclusions.) "At present, ***any other type of parallel process*** must be done by the user and the compiler automation of the task ***is fairly distant***." (Page 8, under Conclusions, emphases added.)

<u>Nonobviousness of Claims 1, 2 and 14</u>

The cited prior art references, Haugen, Briens, Watts, and Scott, alone or in combination do not teach or suggest each element of any one of the independent claims. <u>For example</u>:

- The cited references do not teach or suggest coupling multiple reservoir simulations with a surface ***network*** simulation, and balancing the coupled network simulation at each controller time step.

- The cited references do not teach or suggest achieving a ***common fluid model*** between running reservoir simulations, in which the common fluid model is composed of a ***super-set*** of pseudo-components.

- The cited references do not teach or suggest selecting a maximum ***synchronization duration*** to define controller time steps and then ***dynamically varying the duration*** of the controller time steps in response to a production rate or an injection rate of one of the reservoir simulations.

- The cited references do not teach or suggest applying the dynamically varying controller time steps to all coupled simulations, while allowing <u>each</u> coupled simulation take a ***different number*** of ***non-identical time steps*** to advance to the start of a next controller time step.

Since the cited prior art references, Haugen, Briens, Watts, and Scott, alone or in combination, do not teach or suggest each element of any one of the independent claims, the Applicant submits that these claims are allowable over the

cited references, and requests that the 35 USC § 103(a) rejection of claims 1, 2, and 14 be removed, in favor of allowance of the claims.

Claims 9-13

Claims 9-13 include the all the language and limitations of their base claim, claim 1. Thus, Applicant suggests that since claim 1 is allowable, claims 9-13 are allowable in turn.

Claims 3-4 and 6-8

Claims 3-4 and 6-8 include the all the language and limitations of their base claim, claim 2. Thus, Applicant suggests that since claim 2 is allowable, claims 3-4 and 6-8 are allowable in turn.

Claims 15-20

Claims 15-20 include the all the language and limitations of their base claim, claim 14. Thus, Applicant suggests that since claim 14 is allowable, claims 15-20 are allowable in turn.

Conclusion

Applicant submits that the pending Claims 1-4 and 6-20 are in condition for allowance and respectfully requests issuance of the subject application.

Respectfully Submitted,

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